Update: Performance of a NOx SCR Design for High Efficiency at High Concentration, Dust and SOx Loading

Presented by: Robert W. Hernquist, Catalytic Product Manager, Huntington Environmental Systems, 1501 E. Woodfield Rd. Suite 200W, Schaumburg, IL 60173; phone (847) 706-6950, fax (847) 706-6954; e-mail: Hernquis@Huntington1.com

Last year I presented a paper on a new NOx SCR system that had not yet started up. This paper presents a review of performance of the system over the first nine months of operation. During this time, initial catalyst activity decreased over time at the initial operating temperature. Several on-line and off-line tests were performed. This led to adjustments that returned the system to performance within specification and provided operating benchmarks for the future.

A manufacturer presented a difficult application for traditional SCR systems. Two process gas streams varied in flowrate and concentration. One stream contained a high level of NOx, while the other had a high ammonia level. Both streams had a high inorganic dust loading, even after passing through dust collectors. The measured SOx levels were high, with even higher theoretical concentrations projected. The NO/NO_2 ratio varied, and the operating temperature increased significantly from beginning to end of the process operating cycle. The customer required a NOx efficiency above 95% and an ammonia emission rate that required the efficiency above 99%, even including slip. Table 1 shows the design conditions.

The system design team found several pitfalls. Fluctuating flowrates and temperatures challenge the mechanical design for even flow distribution, for good mass and heat transfer rates, and challenge the safety design for any direct-fired unit. The successful design must also handle the following five special process concerns that could have led to frequent breakdown or might severely limit abatement efficiency. First, it was necessary to preheat the streams to 400 °F before combining to avoid forming ammonium nitrate. Likewise, we would add vaporized aqueous ammonia to the process for the same reason. Second, the inlet NOx concentration was so high that dilution was necessary to minimize exothermic reaction temperature rise. SCR catalysts display a maxima point in the efficiency versus temperature curve that limits the useful temperature range at high efficiency. Third, after the outlet of the catalyst bed, unreacted ammonia could combine with sulfur trioxide to form ammonium bisulfate. This material would condense out in cooler regions, plugging equipment and corroding it. Fourth, the design must convey particulate materials through the unit without trapping them or eroding fragile catalyst surfaces. Fifth, feedback ammonia control had to operate without the inlet NOx measurement. The successful system will have avoided all of these pitfalls.

The design required cooperation between engineering, testing and development. Catalyst testing was necessary to guarantee efficiency. Early test data determined that at least two beds were necessary for more than 93% efficiency. Tests suggested using Econ-NOx ZX1 catalyst in the first bed. This bed would operate at higher-than-normal ammonia/NOx ratios and a temperature below the maxima to SOx suppression. Excess ammonia would pass to the second bed with the reduced NOx flow. The second bed would contain lower temperature Econ-NOx ZCX1 catalyst. This bed would operate at a temperature above the maxima, reducing NOx and scavenging ammonia to nitrogen and water.

With some dilution from the required vaporizer carrier air, no additional dilution was necessary. This hybrid catalyst system provided the solution to the efficiency problem. The catalysts had a very low oxidation of SO_2 to SO_3, less than 1% at normal temperature. When the catalyst does not oxidize SOx, there is no increase in the potential for ammonium salts formation. Figure 1 presents the expected performance curve for the SCR with the dual beds.

Preliminary engineering then addressed particulate handling and ammonium salt prevention. The fluidized bed of non-precious metal zeolite of the Econ-NOx ™ Selective Catalytic Reduction System offered good particulate handling characteristics. Several dirty applications used the Econ-Abator® Catalytic Oxidizer version without catalyst blinding or mechanical flow problems from particulate loading up to 0.03 gr/DSCF. This formed the basis for the Econ-NOx™ SCR version, so that it should perform without particulate problems also. A self-recuperative heat exchanger with two separate inlets, but one outlet, preheated the process streams to more than 400 °F before mixing. Designing a stack temperature above 450 °F limited the overall efficiency of this exchanger to 50%. The aqueous ammonia vaporizer used preheated carrier air from an economiser inserted between the burner and catalyst. The ammonia flow controller varied only ammonia flow while carrier air rate was constant. This minimized the possible maldistribution from the ammonia injection grid with such a large ammonia turndown, as well as combustibility issues. Figure 2 is a process flow scheme of the system.

As of late March 1998, installation of the system was complete and the system has operated for nine months. After startup, the original process development plan was put on hold when the unit passed the initial performance test. The stack testing measured extremely low output concentrations and destruction efficencies of 99.7% for NOx and 99% for ammonia, even with more than 2.5 times stoichiometric ammonia. But after one month, the ammonia slip began increasing. The ammonia control valve trim was changed to a smaller flow range, and the operators began setting and adjusting the process control algorithm. This feedback algorithm uses the stack on-line ammonia and NOx analyzer, and an ammonia flow controller with feedback. While the unit maintained efficiency in normal steady-state operation, upsets led to excessive ammonia slip. The control algorithm was dependent on the robust ammonia scavenging performance of the second bed of catalyst. The change in ammonia output in the stack followed an input change by several minutes. By running a series of performance curves at several operating temperatures, it was clear that the performance of the second bed became more robust with respect to ammonia slip at higher temperature and the catalyst activity was still sufficient for operation within the performance specification. Current status includes improvement in the control algorithm and periodic monitoring of emissions for increase in operating temperature to prevent excessive ammonia slip.

The manufacturer supplied a fluidized bed of zeolite catalyst with custom designed system using pre-designed equipment to handle a difficult application for traditional SCR systems. Warranted emissions required 95+% NOx efficiency and 99+% ammonia efficiency. Measured actual emissions are well within the design performance criteria.

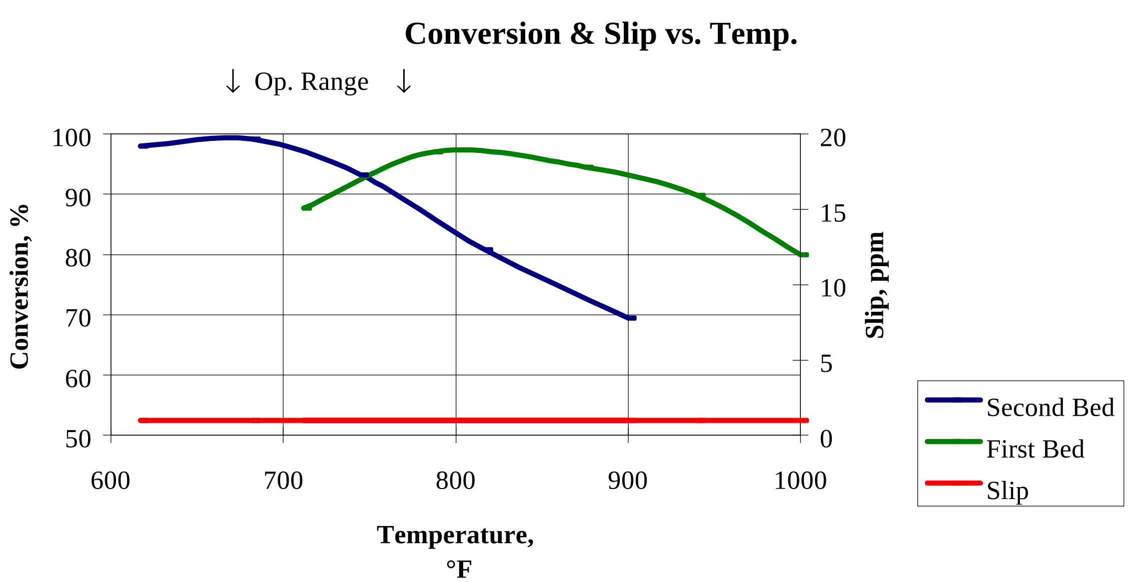
Rev. March 26, 1998

Update: Performance of a NOx SCR Design for High Efficiency at High Concentration, Dust and SOx Loading

TABLE 1
Process Design Conditions

Condition	Variability
Flowrate	2.6 : 1
NOx mass rate	25 : 1
NH_3 mass rate	9.2 : 1
Temperature	increases > 100 °F
Dust Loading	< 0.010 gr/DSCF
NO / NOx ratio	2.1 : 1
SOx mass rate	13.3 : 1
SO_3 / SOx ratio	< 0.10

FIGURE 1
Performance Curve of Catalysts:
First bed = Econ-NOx™ ZX1, Second = Econ-NOx™ ZCX1



Update: Performance of a NOx SCR Design for High Efficiency at High Concentration, Dust and SOx Loading

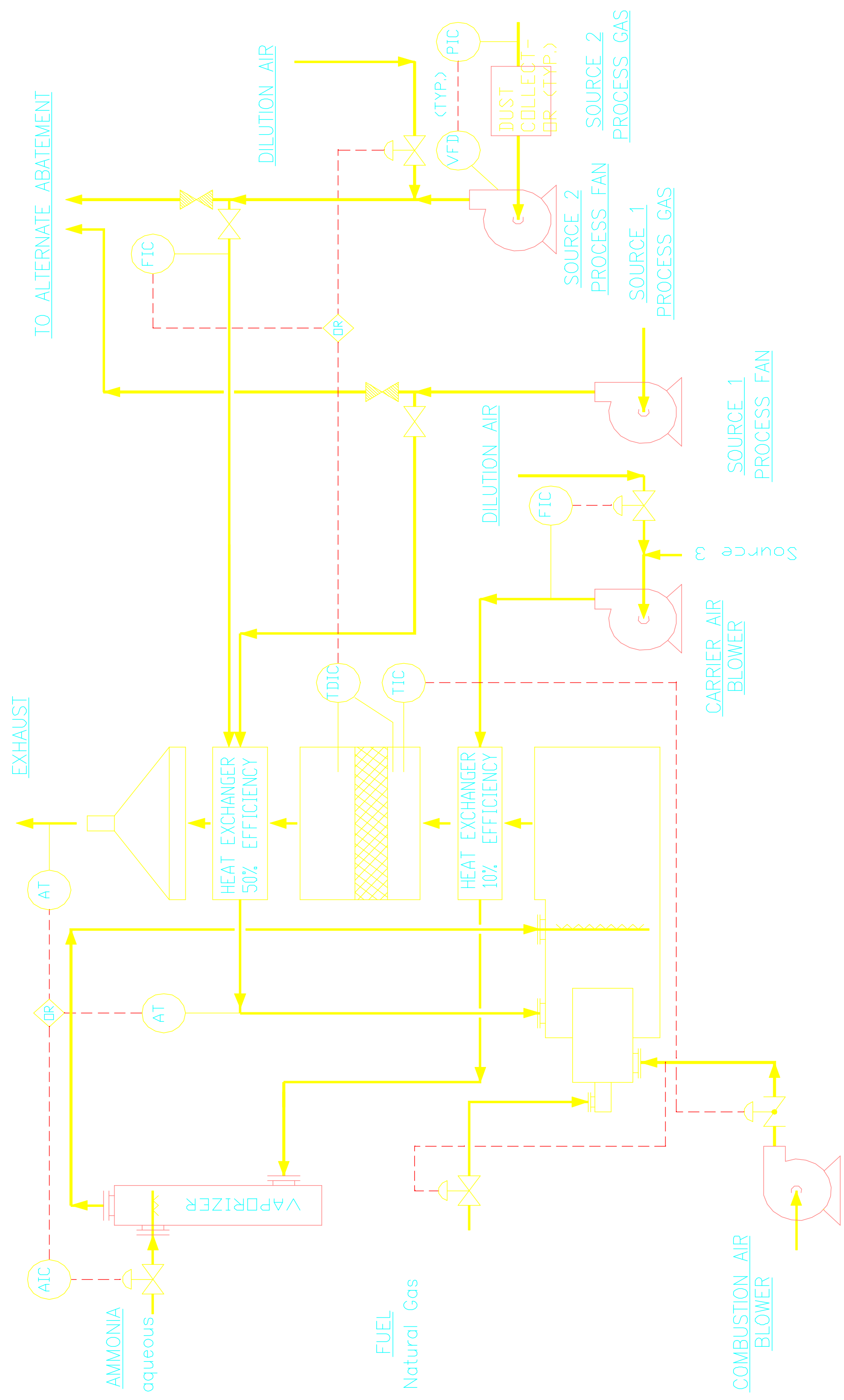


Figure 2
PROCESS FLOW SCHEME
ECON-NOx™ SELECTIVE CATALYTIC REDUCTION SYSTEM

CATALYST ENTRY TEMPERATURE SHOWN IS BEST ESTIMATE AND MAY VARY WITH ACTUAL OPERATING CONDITIONS AND REQUIRED CONVERSION EFFICIENCY.